2011. The Journal of Arachnology 39:420–438

Morphological analysis of montane scorpions of the genus *Vaejovis* (Scorpiones: Vaejovidae) in Arizona with revised diagnoses and description of a new species

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Abstract. Several scorpions of the genus *Vaejovis* in Arizona are restricted in range to mountain-top forests. These scorpions, informally referred to as the "*vorhiesi* complex" are very similar morphologically, but their geographic distribution has attracted the attention of several researchers, resulting in the description of a few new species in recent years. However, these species were described from small sample sizes and were diagnosed with questionable characters that were not sufficiently analyzed. This study evaluates the morphology of scorpions of the "*vorhiesi* complex" from seven regions in Arizona to verify the validity of the species and their accompanying diagnoses. Morphological characters examined include morphometrics, hemispermatophores, size and shape of subaculear tubercles of the telson vesicle, pectinal tooth counts, pedipalp chela denticle counts, metasomal setal counts, development of metasomal carinae, and tarsal spinule counts. New diagnoses are given for previously described species (*V. vorhiesi* Stahnke 1940, *V. lapidicola* Stahnke 1940, *V. paysonensis* Soleglad 1973, *V. cashi* Graham 2007 and *V. deboerae* Ayrey 2009), which are considered valid, based on the morphological evidence gathered. A new species of *Vaejovis*, *V. electrum*, is described from the Pinaleño Mountains in Arizona.

Keywords: Morphometrics, discriminant function analysis, sky islands, *mexicanus* group

The family Vaejovidae is the most diverse and speciose group of scorpions in North America (Sissom 2000). Some species are known from as far north as southwestern Canada and as far south as Guatemala in Central America (Sissom & Francke 1981; Sissom 1989). Two qualities that contribute to this high diversity are the low dispersal capabilities and high substrate fidelity of vaejovids. There are, for example, vaejovid scorpions that specialize in rocky habitats and live in the cracks and crevices of rock faces (e.g., *Serradigitus* spp., *Vaejovis nitidulus* group) and others that are restricted to sandy habitats, including sand dunes (e.g., *Paruroctonus, Vejovoidus*) (Prendini 2001).

Within the family Vaejovidae, the genus *Vaejovis* is by far the largest, with 74 species, and is the third largest genus of scorpions in the world (see www.vaejovidae.com). Within the genus, there are five species groups: the *eusthenura* group, the *intrepidus* group, the *mexicanus* group, the *nitidulus* group, and the *punctipalpi* group. Several species are not placed in any of these groups. There is much doubt among current researchers that these groups, or the genus *Vaejovis* itself, represent monophyletic assemblages. Revisionary systematic work is being conducted to obtain a robust phylogeny of the family and a greater understanding of the relationships between species (www.vaejovidae.com).

Within the *mexicanus* group there is a collection of species informally referred to as the "*vorhiesi* complex" (although some exclude *V. vorhiesi* from the *mexicanus* group: Santibáñez-López & Francke 2010). The "*vorhiesi* complex" is a group of small (approximately 20–30 mm), brown, mottled scorpions that live in the mountains of the Madrean archipelago, a group of mountain "islands" found between the Sierra Madre Occidental range of northern Mexico and the Rocky Mountain range of the United States (Warshall 1994). These scorpions are generally found at elevations above 2100 m, where they dwell in the pine or oak litter of the mountain forests (Sissom 2000). The currently described species of the "*vorhiesi* complex" in Arizona include *V. vorhiesi* Stahnke 1940; *V. lapidicola* Stahnke 1940; *V. paysonensis* Soleglad 1973; *V. cashi* Graham 2007; and *V. deboerae* Ayrey 2009. Another species, *V. feti* Graham 2007, is known from the Black Range of New Mexico, but it may occur in Arizona as well because the Black Range is considered a part of the San Francisco Mountains, which extend into Arizona. Most recently, *V. montanus* was described from the Sierra Madre Occidental in Mexico (Graham 2010), but this description was published after completion of the current study so is not included in my analyses.

The fact that these scorpions are restricted to the mountain top forests has led to speculation that each isolated population is a distinct species (Graham 2007; Ayrey 2009). This hypothesis is derived from the understanding that isolated populations tend to diverge through time because of random genetic drift or selection for different traits. It is currently estimated that populations of the "*vorhiesi* complex" were isolated from one another around 10,000 years ago when forests covering most of Arizona retreated up the mountains coincident with the end of the most recent ice age (Anderson 1993; Maddison & McMahon 2000). Authors have described new species from these areas within the last few years based on dubious morphological differences (Graham 2007; Ayrey 2009). Almost all published species descriptions to date have been based on very low sample sizes: one male and one female specimen for *V. vorhiesi* (from different mountain ranges) (Stahnke 1940), two females for *V. lapidicola* (Stahnke 1940), seven females and four juveniles for *V. paysonensis* (Soleglad 1970), two females for *V. cashi* (Graham 2007), and a male and female for *V. feti* (although the author suggests that "many" were examined) (Graham 2007). Only the study by Ayrey (2009) utilized larger sample sizes, approximately 30 specimens including both males and females, for *V. deboerae*. Ayrey (2009) also listed 17 specimens of *V. vorhiesi* used in comparisons. Using robust

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sample sizes is important in taxonomic work, especially when only considering morphological characters, because it reveals the extent of intraspecific variation. Without this knowledge, species may be described from characters that are not diagnostic of species-level differences. At the extreme, new species may even be described from variants of a previously described species. Furthermore, specimens should be from as many localities as possible because slight environmental differences could result in morphological differences.

The purpose of this study was to gather more complete data from a much larger sample of specimens and on a wider variety of morphological characters from seven geographically proximal groups of scorpions (mostly from mountain systems) in Arizona to assess the validity of previous species descriptions and discover non-overlapping, or at least minimally overlapping, characters that can distinguish populations or groups of populations.

Taxonomic History.—*Vaejovis vorhiesi* and *V. lapidicola* were first described by Stahnke (1940). *Vaejovis vorhiesi* was described from specimens collected in the Huachuca and Santa Catalina Mountains in southeastern Arizona. *Vaejovis lapidicola* was described from an area 1.6 km east of Flagstaff. Unfortunately, Stahnke's (1940) published descriptions were merely short paragraphs that provided few details of the species. One can discern differences between these two species from his published descriptions, but his unpublished dissertation (Stahnke 1939) clearly reveals the differences he considered most important in a dichotomous key. By examining the species descriptions one can find additional differences, such as differing numbers of pectinal lamellae with five to seven in *V. lapidicola* and six to eight in *V. vorhiesi.* Stahnke's (1939) dissertation yields two additional differences. The first difference is the relative length-to-width ratio of the fifth segment of the metasoma, with *V. lapidicola* having this segment more than twice as long as wide and *V. vorhiesi* with this segment equal to or less than twice as long as wide. Another distinction is that the intercarinal spaces of the ventral surface of the fifth metasomal segment differ in their granulation, with *V. lapidicola* having coarsely granular intercarinal spaces and *V. vorhiesi* having smooth to finely granular spaces (Stahnke 1939).

Soleglad (1973) created the *mexicanus* group of the genus *Vaejovis* and placed *V. lapidicola* and *V. vorhiesi* into this group. The *mexicanus* group was defined by the following characters: female genital operculum divided on posterior one-fifth; pedipalp chela fixed finger length equal to or longer than the pedipalp chela width; inner ventral carina of the palm of the chela "obsolete, suppressed, or well-developed"; trichobothria *ib* and *it* on the base of the finger and not on the palm; carapace indented on the anterior margin but not deeply bilobed; and ratio of total length to pectinal tooth count 1.91–2.95 for males and 1.87–3.50 for females. Soleglad (1973) described a new species, *V. paysonensis* from 40.23 km (25 mi) northeast of the city of Payson, Arizona. *Vaejovis paysonensis* was not compared to *V. lapidicola*, despite its closer proximity in both form and geography. However, Soleglad (1973) compared his new species to *V. vorhiesi*, distinguishing them by means of the following traits: seven inner accessory denticles on the pedipalp chela movable fingers in *V. paysonensis* and six in *V. vorhiesi.* There are 11–13 pectinal teeth for both males and females in *V. paysonensis* and 15 in males and 12–13 in females of *V. vorhiesi.* The ratio of chela palm width to chela length in *V. paysonensis* is 15/52 and in *V. vorhiesi* is 12/50. Finally, Soleglad (1973) reported lighter coloration in *V. paysonensis.*

Graham (2006) redescribed *V. lapidicola* from the two syntypes in poor condition and one other female. The major alteration made to the description is coloration, which may have changed in 48 years since the specimen was collected and preserved. In addition, he added measurement data that were lacking in the first published description, although Stahnke (1973) did include measurements in his unpublished dissertation. Graham (2006) identified *V. paysonensis* as the species most similar to *V. lapidicola* based on the possession of seven inner accessory denticles on the pedipalp chela movable finger. He distinguished *V. lapidicola* as having a more planate (flattened) carapace. Also, the ratios of carapace length over width, with width measured at the median eyes, are reported as 1.25 and 1.44 for *V. lapidicola* and *V. paysonensis*, respectively. There was no indication of whether these ratios are averages or from single specimens.

Graham (2007) described *V. cashi*, from the Chiricahua Mountains, and *V. feti*, from the Black Range in New Mexico, along with a redescription of *V. vorhiesi.* Graham (2007) distinguished *V. vorhiesi* from the other two species by its larger size, lighter pigment patterns, and the presence of 6–7 denticles on the third denticle row of the pedipalp chela movable finger instead of 8–9 as is found in *V. cashi* and *V. feti.* The latter two are diagnosed by coloration (*V. cashi* is red or mahogany and *V. feti* is brown) and by the presence (*V. cashi*) or absence (*V. feti*) of a subaculear tubercle of the telson.

The most recently described species of the "*vorhiesi* complex" in Arizona was *V. deboerae* (Ayrey 2009). *Vaejovis deboerae* is restricted to the Santa Catalina Mountains of Arizona. Ayrey (2009) presented a table comparing measurements and morphometric ratios using only type females of *V. vorhiesi*, *V. cashi*, and *V. feti*, and using the holotype of *V. deboerae* with two other specimens (a paratype male and female). However, the only measurements included from the two paratypes were total length and carapace length, and the only ratio used was metasomal length/carapace length. He used multiple specimens for pectinal tooth counts. Ayrey (2009) diagnosed *V. deboerae* from *V. vorhiesi*, *V. cashi*, and *V. feti* based on overall body size, apparently based on the measurements of only type specimens. He compared morphometric ratios of *V. deboerae* and *V. vorhiesi*, reporting differences in means of ratios, suggesting multiple specimens were measured, though no sample size was reported. *Vaejovis deboerae* was also indicated as being different from the others in having lighter legs and a darker body, heavier granulation, enlarged dorsolateral carinae of metasomal segment I, the presence of an enlarged spinoid denticle on the distal end of the dorsolateral carinae of metasomal segment IV, longer lateral inframedian carinae on metasomal segments II–III, and lateral inframedian carinae present on the distal 2/5 of metasomal segment IV. Ayrey (2009) compared pectinal tooth counts using the mean count of each population and performed student's *t*-tests pair-wise between *V. deboerae* and *V. vorhiesi, V. cashi, and V. feti.* All 3 tests were statistically significant, even though the means for *V. deboerae* and *V. vorhiesi* were 11.89 and 12.39, respectively, which, if rounded to the whole numbers that pectinal teeth are counted as, may both be considered 12 and therefore may not truly be diagnostic. Because only means are reported, no sense of the true overlap observed by Ayrey (2009) can be obtained.

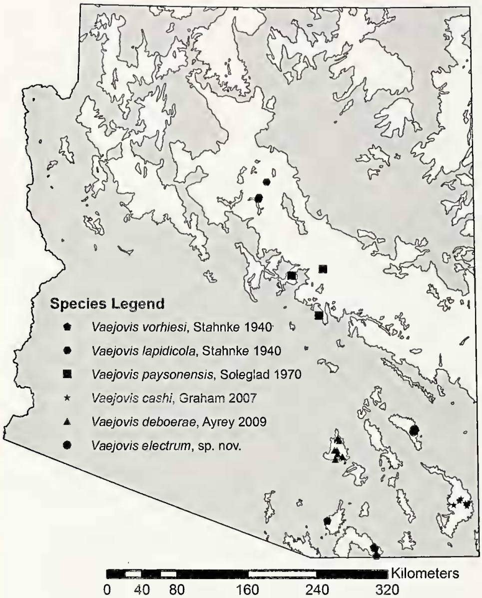

Figure 1.—Distribution map of montane scorpions of the genus *Vaejovis* found in Arizona. Each black shape represents a collecting locality. White areas represent forests in Arizona, usually above 1000 m. Species legend in lower left of map indicates which shapes represent localities for each of the six species.

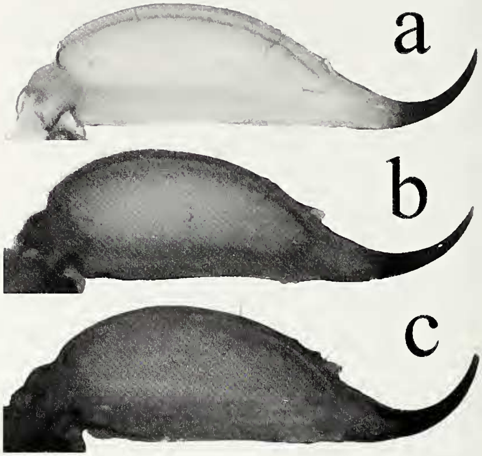

Figure 2.—Development of subaculear tubercles on the telson of *Vaejovis* scorpions. a. single poorly developed tubercle; b. single well-developed tubercle; c. multiple tubercles.

METHODS

Specimens.—Specimens were borrowed from the American Museum of Natural History, New York (AMNH), the California Academy of Sciences, San Francisco (CAS), and W. David Sissom's personal collection (WDS). The specimens examined originated from six mountain ranges in Arizona: Chiricahua, Huachuca, Pinaleño, Santa Catalina, Santa Rita, and Sierra Ancha (Fig. 1). Specimens reported as being from "Payson, AZ" are grouped with the Sierra Ancha specimens because of their relatively close proximity to that range. I also examined specimens from the high elevation area around Flagstaff and Sedona (hereafter collectively referred to as "Sedona"). Each of these areas was used because each has a currently described species of the "*vorhiesi* complex" living there, except for the Pinaleño Mountains.

All data for the Huachuca and Santa Rita Mountains are reported separately to demonstrate the lack of diagnostic characters for those two groups and were also combined to aid in comparison of that species with other species. Combined data from the Huachuca and Santa Rita Mountains are denoted as Huachuca/Santa Rita in the tables.

Meristic Counts.—Pectinal tooth counts for males and females were collected from each population. I examined approximately 730 specimens for pectinal tooth data and recorded the number of times each count was present for each population.

I counted the number of inner accessory denticles on the fixed and movable fingers of both pedipalp chelae for 20 specimens, 10 male and 10 female, from each population. In cases where 20 specimens were not available, as many as were available were counted. I also recorded the number of median denticles on each of the denticle subrows for 6–12 specimens from each of these populations, except Sedona.

Lateral inframedian carinae for metasomal segments II–IV were examined. All carinae began at the distal end of the segment but varied by how far they extended anteriorly. Each carina was categorized by the percentage of the segment it occupied.

Setal maps, containing information on the numbers and patterns of setae on the metasoma, are useful for distinguishing some closely related groups of scorpions (Yahia & Sissom 1996: see Discussion). I created metasomal setal maps for five specimens from each of the seven areas to see if consistent patterns were apparent between species or groups of species, with the intention of recording setal counts and drawing more setal maps if potentially distinguishing features were apparent. Numbers and positions of setae were so varied within species that no further counts were made because there was no prospect of finding distinguishing characters from the setal maps.

Tarsomere spinule counts were examined as described by McWest (2009).

Subaculear tubercles.—Subaculear tubercles were classified into three groups based on the number or development of the tubercle(s): "single poorly developed tubercle", "single well-developed tubercle", and "multiple tubercles" (Fig. 2). I classified individuals with a single bifurcate tubercle as having multiple tubercles. All telsons with multiple tubercles were grouped as "multiple tubercles". The remaining telsons with single tubercles were classified as being "well-developed" or "poorly developed" on the basis of the angle formed between

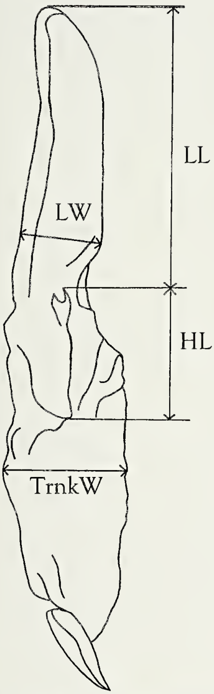

Figure 3.—Diagram of *Vaejovis* hemispermatophore showing measurements. Abbreviations: LL, lamina length; LW, lamina width; TrnkW, trunk width; HL, hook length.

the aculeus and the tip of the tubercle. I categorized tubercles with acute angles as "well-developed" and those with obtuse angles as "poorly developed".

Mensuration.—Right-side hemispermatophores were extracted and examined as described by Sissom et al. (1990: 458). Measurements of hemispermatophores were taken of the lamina length, lamina width, trunk width, and hook length for each of the hemispermatophores (Fig. 3). Lamina length was measured from the tip of the lamina to the top of the hooks. I measured lamina width as a line from the corner of the lamina perpendicular to the opposing lamina edge. Trunk width was measured across the widest part of the trunk with the lamina plane parallel with the plane of the microscope stage. In all measurements, the points were lined up in the same plane of focus to ensure accurate measurement of the distance between the points. Hook length was measured from the bottom of the trough to the top of the hooks. In cases where the hemispermatophore was damaged, I did not measure aspects that were likely to be affected by the damage. For example, the lamina length of laminas that were bent was not measured. Three ratios were constructed from these measurements: lamina length/lamina width, lamina length/hook length and trunk width/hook length.

I measured standard features of the scorpions as described by Sissom et al. (1990:452). It should be noted that the proper interpretation of this figure is that the measurement should be taken between the two points of the feature in contact with the parallel lines, not as a perpendicular measurement between the parallel lines.

A stage micrometer was used to calibrate the ocular scale in the microscope. All measurements were taken in millimeters. I took each measurement with the end points in the same plane of focus, which is necessary to take consistent measurements because the slightest degree of rotation can alter the apparent distance between the two points. Measurements were taken from 20 males and 20 females from each of the populations or as many as were available when there were less than 20. In total, 11 measurements were taken and eight ratios were calculated.

Statistics.—Percent overlap was calculated for each measurement and ratio in pair-wise fashion between each population. I calculated percent overlap by first taking the minimum and maximum values of a measurement or ratio from two different populations. Next, I took the difference between the larger of the two maximum values and the smaller of the two minimum values. This resulted in the overall range for that measurement or ratio. Then the larger of the minimum values was subtracted from the smaller of the maximum values. A positive value meant there was no overlap between the two populations. A negative value meant there was at least some degree of overlap between the two populations. If there was overlap, the difference between the larger minimum and smaller maximum was divided by the difference between the larger maximum and the smaller minimum (the total range) and multiplied by 100. Cases where the minimum and maximum of one population were between the minimum and maximum of the other population were considered as having 100% overlap.

Multiple pair-wise comparisons of data can inflate the type-I error rate. In other words, it makes it more likely to reject a true null hypothesis. Multivariate statistics prevent this phenomenon by considering all data simultaneously. I conducted canonical discriminant function analysis to see if there were differences between the measurements of the populations. The measurements used were carapace length, metasoma segment III length, metasoma segment III width, metasoma segment V length, metasoma segment V width, femur length, femur width, chela length, chela width, fixed finger length, and movable finger length. I conducted the analysis separately for females and males and used the base 10 logarithms of the measurements because the data were not normally distributed. My calculations were performed and figures and tables were created with SPSS 13.0 for Windows Student Version (Apache Software Foundation © 2000).

RESULTS

Meristic and qualitative characters.—Modal pectinal tooth counts were higher for males and females of the Huachuca and Santa Rita Mountains and lower for males and females of the Sierra Ancha Mountains (Table 1). Although pectinal tooth counts overlap greatly depending on whether a given count is expressed in a population, large sample sizes, such as those found in the Chiricahua Mountains, demonstrate that the mode is a useful character because there are typically far more

Table 1.—Distribution of pectinal tooth counts for montane *Vaejovis* scorpions sampled from seven areas in Arizona. The number of single pectines (a single specimen has two pectines) that display a given number of teeth in a geographic area can be found by locating the area on the left and reading across the table. Teeth from both pectines of a specimen were counted as independent pectines unless one was damaged or missing, in which case only teeth from the whole pectine were counted.

		Number of pectinal teeth per pectine									
	Group	9	10	11	12	13	14	15	16	Mean	Mode
Males	Huachuca						7	11	2	14.75	15
	Santa Rita					2	10	50	18	15.05	15
	Huachuca + Santa Rita					2	17	65	20	14.99	15
	Sedona			2	2	12	8			13.08	13
	Sierra Ancha				3	1				12.25	12
	Chiricahua			1	34	233	46	4	1	13.07	13
	Santa Catalina				1	11	6			13.28	13
	Pinaleño				2	28	6			13.11	13
Females	Huachuca			1	38	69				12.59	13
	Santa Rita			2	42	146	40	1		12.98	13
	Huachuca + Santa Rita			3	80	215	40	1		12.87	13
	Sedona	1	1	2	8	1				11.64	12
	Sierra Ancha		10	46	16					11.08	11
	Chiricahua		59	227	50	1				10.98	11
	Santa Catalina			16	44	7	2			11.93	12
	Pinaleño			29	62	5				11.75	12

specimens exhibiting the modal count than other counts, rather than the modal counts being represented by only a few more specimens compared to other counts.

For most groups, the number of specimens whose count of inner accessory denticles along both the movable and fixed pedipalp chela fingers differed from the mode is relatively few (Table 2). However, others have a greater a mount of variability. The Pinaleño and Santa Catalina specimens, for instance, have between 25% and 40% of their specimens differing from the modes. Aside from those two, the general trend observed is that the scorpions in the southeastern portion of Arizona have six and five inner accessory denticles for the pedipalp chela movable and fixed fingers, respectively, while the other scorpions have seven and six.

I found no distinguishing differences in the number of denticles within each median denticle subrow of the fixed and movable fingers of the pedipalp chelae because of the wide overlap between groups (Table 3).

Wide variability in lateral inframedian carinal development for metasomal segments II–IV rendered this character useless in distinguishing these groups from one another (Tables 4–6).

The Huachuca, Santa Rita, Sedona, and Sierra Ancha specimens had a majority of specimens with one poorly developed tubercle. The Pinaleño specimens mostly had

Table 2.—Distribution of inner accessory denticle counts on the pedipalp chela fingers for montane *Vaejovis* scorpions sampled from seven geographic areas in Arizona. The values in the middle of the table indicate the number chela fingers that display the given number of denticles (as labeled at the top of the column) found from a sample of individuals from a geographic area (as labeled at the left of the row). Mean and modal counts are presented on the right.

		# Inner accessory denticles						
Pedipalp chela finger	Group	4	5	6	7	8	Mode	Mean
Movable	Huachuca		5	35			6	5.9
	Santa Rita		6	34			6	5.9
	Huachuca + Santa Rita		11	69			6	5.9
	Sedona			4	35	1	7	6.9
	Sierra Ancha		2	1	37		7	6.9
	Chiricahua		3	37			6	5.9
	Santa Catalina		2	38			6	6
	Pinaleño	1		38			6	6
Fixed	Huachuca	1	39				5	5
	Santa Rita	1	39				5	5
	Huachuca + Santa Rita	2	78				5	5
	Sedona			40			6	6
	Sierra Ancha		2	38			6	6
	Chiricahua	2	38				5	5
	Santa Catalina		11	29			6	5.7
	Pinaleño		24	16			5	5.4

Table 3.—Ranges in the number of denticles found on each subrow of the median denticles row on the pedipalp chela fingers of montane *Vaejovis* scorpions from six geographic areas in Arizona. Each column of numbers represents a different subrow of median denticles and columns are listed left to right from most distal to most proximal. Note the variation and overlap between populations.

Group	Movable finger						Fixed finger						Sample size
	Distal end			Proximal end			Distal end			Proximal end			
Huachuca	0–2	5–8	7–10	8–10	7–10	16–25	4–6	6–9	7–9	6–9	7–10	14–24	11
Santa Rita	1–2	5–7	6–10	7–10	7–10	16–27	3–7	5–8	6–10	6–9	7–9	13–27	10
Sierra Ancha	1–2	6–8	8–10	8–11	8–10	19–25	5–8	7–9	7–10	6–9	7–9	15–22	6
Chiricahua	0–2	4–7	6–9	7–9	7–9	18–24	4–6	5–7	6–8	6–8	6–9	12–18	12
Santa Catalina	0–2	6–8	7–9	7–9	8–0	19–28	4–7	6–9	7–9	5–9	6–10	14–26	10
Piñaleno	0–2	4–7	7–9	6–9	6–11	17–27	2–6	6–7	6–9	6–8	7–10	1–29	10

multiple tubercles. The Chiricahuas had about half with multiple tubercles and half with well-developed tubercles, but none with poorly developed tubercles. The Santa Catalina specimens mostly had a single well-developed tubercle (Table 7).

The setal positioning as determined from the setal maps varied widely, and no distinguishing differences were found from it (Fig. 6). Tarsomere II spinule counts also appeared inconsistent and counts overlapped greatly between populations.

Morphometric characters.—Gross morphology of hemispermatophores appeared quite variable. I found many potential characters to be absent from specimens within a population but present in specimens from other populations. However, ratios of measurements from the hemispermatophores did reveal some differences. In particular, the Chiricahua specimens had much shorter laminas relative to the hook length. This ratio was consistently smaller and non-overlapping with any other group (Table 8).

Female measurements and ratios seemed less able to distinguish species than male measurements and ratios (Tables 9, 10). Perhaps the most frequent distinguishing difference between two species is the metasomal segment III length-over-width ratio. Chela length-over-width ratios were also informative.

Discriminant function analysis.—The discriminant function analyses created six functions because there were seven populations. Of these, the first two are responsible for most of the differences between groups (Figs. 4, 5). For the females, function 1 was most highly correlated with metasoma segment III width, but none of the correlations between function 1 and the measured features were very high. Function 2, however, was very highly correlated with all the measured features. For the males, function 1 was most highly correlated with chela width. Function 2 was highly correlated with all the remaining measured features, but of those the two metasomal length measurements contributed the most. The male groups were separated with little overlap when plotted. The groups with the most overlap were Santa Rita, Santa Catalina, and Huachuca, which is interesting because these mountain ranges are fairly close to one another. The plot of female specimens had a lot more overlap. The Santa Catalina group was the only one that did not overlap with any other group. SPSS also reclassified all specimens using the discriminant functions it created (Tables 11, 12). The male reclassification had a higher percent of correct reclassification (95.7%) than the female reclassification (86.8%). This was likely an effect of the difference ingroup overlap mentioned above.

DIAGNOSIS

The following diagnoses refer to the currently described *mexicanus* group scorpions from Arizona and use the scientific names. For these diagnoses, my study locations refer to the following species: Huachuca = *V. vorhiesi* in part; Santa Rita = *V. vorhiesi* in part; Huachuca/Santa Rita = *V. vorhiesi* using combined data from the Huachucas and Santa Ritas; Sedona = *V. lapidicola*; Sierra Ancha = *V. paysonensis*; Chiricahua = *V.*

Table 4.—Distribution of development of lateral inframedian carina of metasomal segment II on montane *Vaejovis* scorpions sampled from seven geographic areas in Arizona. Carinal development is expressed as percent of sample size exhibiting a given amount of carinal development. Development of the lateral inframedian carina of metasomal segment II is expressed as proportion of the segment that has the carina present. All lateral inframedian carinae begin at the posterior end and extend anteriorly. For example, 14.3% of the 21 Santa Rita specimens had carinae that extended half way along the length of the segment from the posterior end.

Group	% Specimens with inframedian carina II extending anteriorly												Sample size
	0	1/5	1/4	1/3	2/5	1/2	3/5	2/3	3/4	4/5	5/6	1/1	
Huachuca							27.7		4.5	59.1	4.5	9.1	22
Santa Rita						14.3	9.5			47.6	23.8	4.8	21
Huachuca + Santa Rita						7.0	16.3		2.3	53.5	14.0	7.0	43
Sedona			11.1	11.1	22.2	22.2	11.1		11.1	11.1			9
Sierra Ancha				4.5	13.6	31.8	13.6			27.3	4.5	4.5	22
Chiricahua			4.5			3.2	4.5	13.6	13.6	22.7	9.1		22
Santa Catalina					4.2	4.2	8.3			50.0	4.2	29.2	24
Pinaleño					4.3			8.7	4.3	47.8	26.1	8.7	23

Table 5.—Distribution of development of lateral inframedian carina of metasomal segment III on montane *Vaejovis* scorpions sampled from seven geographic areas in Arizona. Carinal development is expressed as percent of sample size exhibiting a given amount of carinal development. Development of the lateral inframedian carina of metasomal segment III is expressed as proportion of the segment that has the carina present. All lateral inframedian carinae begin at the posterior end and extend anteriorly.

Group	% Specimens with inframedian carina IV extending anteriorly												Sample size
	0	1/5	1/4	1/3	2/5	1/2	3/5	2/3	3/4	4/5	5/6	1/1	
Huachuca	50.0	13.6			22.7	9.1				4.5			22
Santa Rita	28.6	4.8	4.8		28.6	9.5	9.5			14.3			21
Huachuca + Santa Rita	39.5	9.3	2.3		25.6	9.3	4.7			9.3			43
Sedona	88.9	11.1											9
Sierra Ancha	50.0		13.6	9.1	13.6	9.1				4.5			22
Chiricahua	7.7		1.5	23.1	15.4	15.4			15.4		7.7		22
Santa Catalina	29.2	4.2			33.3	4.2				25.0			24
Pinaleño	26.1	4.3	8.7		8.7	27.1			8.7	21.7			23

cashi; Santa Catalina = *V. deboerae*. A new species from the Pinaleño Mountains is described following the other diagnoses.

Vaejovis vorhiesi Stahnke 1940

Vejovis vorhiesi Stahnke 1940:102 (original description); Soleglad 1973:359, 361, 363, 364; Stahnke 1974:135.

Vaejovis vorhiesi: Sissom 1991:221–222; Sissom 1997:13; Kovarík 1998:148; Graham 2006:3, 6; Graham 2007:1–6, 9, 10, 13; Ayrey 2009:1, 3, 5–9, figs. 7, 9, 12, 13.

Type material.—Lectotype: adult female, Miller Canyon (31°24′N, 110°17′W), Huachuca Mountains, Cochise County, Arizona, USA (CAS Type No. 15172); not examined. A second specimen (a paralectotype), a male from the Santa Catalina Mountains, is referable to *V. deboerae* Ayrey 2009.

Material examined.—USA: *Arizona*: Cochise County, Huachuca Mountains: Ramsey Canyon, 31°26′N, 110°18′W, 10–15 July 1941, A.B. Klots, 1 male (AMNH); Montezuma Pass, 31°21′N, 110°17′W, 1829 m, 4 June 1952, M. Cazier, W. Gertsch & R. Schrammel, 1 female (AMNH); Sierra Vista, 31°32′N, 110°16′W, 2134 m, under rocks, 17 July 1971, G. Bawden, 3 females (AMNH); Carr Canyon, 31°26′N, 110°17′W, 3 June 1952, M. Cazier, W. Gertsch & R. Schrammel, 2 males, 19 females, 1 juvenile (AMNH); Carr Canyon Rd., 1.8 km NNE Carr Peak, 31°25′N, 110°17′W, 2195 m, 19 June 1976, 2 females (AMNH); Carr Canyon, 31°26′N, 110°17′W, 2289 m, 31 July 1949, W.J. & J.W. Gertsch, 3 males, 13 females (AMNH); Upper Carr Canyon, 31°25′N, 110°18′W, 22 July 1955, W.J. Gertsch, 3 males, 7 females (AMNH); Lower Carr Canyon, 31°26′N, 110°17′W, 21 July 1955, W.J. Gertsch, 1 female (AMNH); Carr Canyon, in pines, 31°25′N, 110°17′W, 9 May 1961, W.J. Gertsch, 1 male (AMNH); 1.6 km W of Montezuma Pass, 31°21′N, 110°17′W, 6 September 1950, 2 females (AMNH); Coronado National Forest, Carr Canyon, Carr Canyon Road, rocky road cut slope, 31°26.069′N, 110°16.909′W, 1972 m, 21 June 2006, W. Savary, R. Mercurio, 2 males (AMNH/AMNH-ARA 00002511); Coronado National Forest, Carr Canyon, Carr Canyon Road, rocky road cut slope, 31°25.909′N, 110°17.053′W, 2112 m, 21 June 2006, W. Savary, R. Mercurio, 2 males, 1 female (AMNH/AMNH-ARA 00002516); Coronado National Forest, Carr Canyon, Carr Canyon Road, rocky road cut slope, 21 June 2006, W. Savary, R. Mercurio: 31°25.946′N, 110°17.052′W, 2061 m, 2 females (AMNH-ARA 00002512) & 31°25.812′N, 110°17.208′W, 2188 m, 3 males, 5 females, 2 subadult males, 1 juvenile (AMNH/AMNH-ARA 00002508)(AMNH). Santa Cruz Co., Santa Rita Mountains: Box Canyon, 31°47′N, 110°46′W, 29 August 1952, B. Malkin, 1 female (AMNH); Madera Canyon, 31°42N, 110°52′W, 7 June 1952, M. Cazier, W. Gertsch, R. Schrammel, 3 males, 41 females, 1 juvenile (AMNH) & 31 July 1952, Nutting, Warner, 1 female (AMNH) & O. Bryant, 1 female, 1 juvenile (AMNH); along trail to Mt. Wrightson, 31°42N, 110°52′W, 21 September 1970, R.C.A. Rice, 23 males, 20 females, 7 juveniles

Table 6.—Distribution of development of lateral inframedian carina of metasomal segment IV on montane *Vaejovis* scorpions sampled from seven geographic areas in Arizona. Carinal development is expressed as percent of sample size exhibiting a given amount of carinal development. Development of the lateral inframedian carina of metasomal segment IV is expressed as proportion of the segment that has the carina present. All lateral inframedian carinae begin at the posterior end and extend anteriorly.

Group	% Specimens with inframedian carina III extending anteriorly												Sample size
	0	1/5	1/4	1/3	2/5	1/2	3/5	2/3	3/4	4/5	5/6	1/1	
Huachuca						9.1	22.7			59.1	4.5	4.5	22
Santa Rita						9.5	9.5		9.5	52.4	14.3	4.8	21
Huachuca + Santa Rita						9.3	16.3		4.7	55.8	9.3	4.7	43
Sedona			33.3	33.3		33.3							9
Sierra Ancha			13.6	4.5	40.9	13.6	9.1			13.6	4.5		22
Chiricahua		4.5	4.5	18.2		27.3		4.5	13.6	18.2	9.1		22
Santa Catalina					8.0	12.0	8.0			52.0	8.0	12.0	24
Pinaleño			4.3		13.0	4.3	8.7	4.3	17.4	26.1	17.4	4.3	23

Table 7.—Development of subaculear tubercles in montane *Vaejovis* sampled from seven geographic areas in Arizona expressed as percentage of specimens examined from each area that displayed a given condition of subaculear tubercle. Sample sizes of specimens examined from each area are given on the right.

Group	% Sample whose telson exhibits each state of subaculear development			Sample size
	Multiple tubercles	1 Well-developed	1 Poorly developed	
Huachuca	0	0	100	85
Santa Rita	1	0	99	102
Huachuca + Santa Rita	1	0	99	187
Sedona	3	7	90	30
Sierra Ancha	20	8	72	36
Chiricahua	50	50	0	107
Santa Catalina	22	65	13	43
Pinaleño	77	20	3	61

(AMNH) & 22 August 1966, S.C. Williams, 3 males (CAS); Big Rock Camp, 31°42N, 110°52'W, 10 September 1941, W. Ivie, 1 female (AMNH); Roundup Camp, 31°42'N, 110°52'W, 11 September 1941, W. Ivie, 2 females, 12 juveniles (AMNH) & 23 March 1960, W.J Gertsch, W. Ivie & R. Schrammel, 12 females (AMNH) & 27 July 1949, W.J. & J.W. Gertsch, 2 males, 7 females (AMNH) & 27 July 1949, W.J. & J.W. Gertsch, 5 males, 15 females (AMNH) & 15 August 1955, W.J. Gertsch, 1 male, 1 female (AMNH) & 13 September 1963, W.J. Gertsch, 1 male, 3 females (AMNH) & 19 July 1962, W.J. Gertsch, 1 male, 3 females (AMNH) & 19 July 1949, W.J. Gertsch, 1 male, 3 females (AMNH); Madera Canyon, 31°42N, 110°52'W, 29 March 2008, B. Anderson & D. Crump, 31°42.875'N, 110°52.6625'W, 1 subadult female, 1 female (AMNH/AMNH LP 8336); above Mt. Wrightson Trailhead Parking, 31°42'N, 110°52'W, 25 July 2008, H.M. Burrell & K.J. McWest, 31°42.72666'N110°52.43832'W, 2 females (AMNH/AMNH LP 8960). Pima County, Santa: Cave Creek Canyon into Florida Canyon, trail at end of Gardner Canyon Road, 20 July 2008, K. Ksepka & M. Rubio, 1 female, (AMNH/AMNH LP 8931).

Diagnosis.—Specimens from the Huachuca Mountains and the Santa Rita Mountains can be considered as a single species, because there are no characters that distinguish one from the other. This species is identified as *V. vorhiesi* because the lectotype of the species selected by Graham (2007) was taken from the Huachuca Mountains. It can be distinguished from the other scorpions in this group by having higher pectinal tooth counts with male mode 15, range 13–16 and female mode 13, range 11–15.

Vaejovis vorhiesi can be distinguished from *V. lapidicola* and *V. paysonensis* by having fewer inner accessory denticles on the pedipalp chela fingers with 5 on fixed finger (6 in *V. lapidicola* and *V. paysonensis*) and 6 on movable finger (7 in *V. lapidicola* and *V. paysonensis*). *Vaejovis vorhiesi* can be further distinguished from *V. lapidicola* by the following features (*V. lapidicola* features follow in parentheses): stouter metasoma segment III, with length/width ratio ranging from 2.40–3.19

Table 8.—Hemispermatophore ratios that overlap by 10% or less between two groups of montane *Vaejovis* scorpions grouped by seven geographic areas in Arizona. Actual percent overlap is listed in the column on the right.

Male hemispermatophore ratios with 10% overlap or less			
Group 1	Group 2	Measurement or ratio	% Overlap
Huachuca	Sierra Ancha	Lamina L/Lamina W	0
Huachuca	Sierra Ancha	Lamina L/Hook L	0
Huachuca	Sierra Ancha	Trunk W/Hook L	2.93
Huachuca	Chiricahua	Lamina L/Hook L	0
Santa Rita	Sedona	Lamina L/Lamina W	0
Santa Rita	Sierra Ancha	Lamina L/Hook L	0
Santa Rita	Sierra Ancha	Trunk W/Hook L	2.21
Santa Rita	Chiricahua	Lamina L/Lamina W	0
Santa Rita	Chiricahua	Lamina L/Hook L	0
Huachuca/Santa Rita	Sierra Ancha	Lamina L/Lamina W	0
Huachuca/Santa Rita	Chiricahua	Lamina L/Hook L	0
Sedona	Sierra Ancha	Trunk W/Hook L	0
Sedona	Chiricahua	Lamina L/Hook L	0
Sedona	Chiricahua	Trunk W/Hook L	0
Sierra Ancha	Chiricahua	Lamina L/Hook L	0
Sierra Ancha	Santa Catalina	Lamina L/Hook L	2.71
Chiricahua	Santa Catalina	Lamina L/Hook L	0
Pinaleño	Santa Rita	Lamina L/Hook L	0
Pinaleño	Sedona	Trunk W/Hook L	0
Pinaleño	Chiricahua	Lamina L/Hook L	0

Table 9.—Female measurements and ratios that overlap by 10% or less between two groups of montane *Vaejovis* scorpions grouped by seven geographic areas in Arizona. Actual percent overlap is listed in the column on the right.

Female measurements/ratios with 10% overlap or less			
Group 1	Group 2	Measurement or ratio	% Overlap
Huachuca	Sedona	III L/III W	6.35
Huachuca	Sierra Ancha	III W	7.88
Huachuca	Sierra Ancha	ChL/ChW	1.34
Huachuca	Sierra Ancha	FFL/ChL	0
Huachuca	Chiricahua	FFL/CaL	9.14
Huachuca	Chiricahua	FFL/ChL	6.2
Huachuca	Santa Catalina	CaL	0
Huachuca	Santa Catalina	III L	9.73
Huachuca	Santa Catalina	ChL	4.61
Huachuca	Santa Catalina	ChW	0
Huachuca	Santa Catalina	FFL	6.12
Santa Rita	Sedona	III L/III W	0
Santa Rita	Sierra Ancha	ChL/ChW	1.5
Santa Rita	Sierra Ancha	MFL/ChW	0
Santa Rita	Sierra Ancha	FFL/ChL	7.4
Santa Rita	Chiricahua	FFL/CaL	5.96
Santa Rita	Santa Catalina	CaL	0
Santa Rita	Santa Catalina	V L	8.69
Santa Rita	Santa Catalina	ChL	4.65
Santa Rita	Santa Catalina	ChW	0
Santa Rita	Santa Catalina	FFL	9.76
Huachuca/Santa Rita	Sedona	III L/III W	6.06
Huachuca/Santa Rita	Sierra Ancha	ChL/ChW	1.34
Huachuca/Santa Rita	Sierra Ancha	FFL/ChL	7.4
Huachuca/Santa Rita	Chiricahua	FFL/CaL	7.99
Huachuca/Santa Rita	Santa Catalina	CaL	0
Huachuca/Santa Rita	Santa Catalina	ChL	4.61
Huachuca/Santa Rita	Santa Catalina	ChW	7.17
Huachuca/Santa Rita	Santa Catalina	FFL	9.44
Sedona	Sierra Ancha	III L/III W	4.03
Sierra Ancha	Santa Catalina	CaL	0
Sierra Ancha	Santa Catalina	III L	0
Sierra Ancha	Santa Catalina	III W	0
Sierra Ancha	Santa Catalina	V W	0.22
Sierra Ancha	Santa Catalina	ChL	8.43
Sierra Ancha	Santa Catalina	FFL	0.19
Sierra Ancha	Santa Catalina	MFL	8.19
Chiricahua	Sedona	III L	3.15
Chiricahua	Sedona	FemL	7.46
Chiricahua	Sedona	ChL	5.05
Chiricahua	Sedona	FFL	7.59
Chiricahua	Sedona	FFL/CaL	0
Chiricahua	Sedona	III L/III W	0
Chiricahua	Santa Catalina	CaL	0
Chiricahua	Santa Catalina	III L	0
Chiricahua	Santa Catalina	III W	3.68
Chiricahua	Santa Catalina	V L	0
Chiricahua	Santa Catalina	V W	0
Chiricahua	Santa Catalina	FemL	4.14
Chiricahua	Santa Catalina	FemW	6.96
Chiricahua	Santa Catalina	ChL	0
Chiricahua	Santa Catalina	ChW	0
Chiricahua	Santa Catalina	FFL	0
Chiricahua	Santa Catalina	MFL	0.39
Pinaleño	Sedona	III L/III W	0
Pinaleño	Chiricahua	V W	7.59
Pinaleño	Santa Catalina	CaL	8.56
Pinaleño	Santa Catalina	V L	5.13
Pinaleño	Santa Catalina	ChL	4.74
Pinaleño	Santa Catalina	ChW	9.63

(3.15–3.78) in females and 0.95–1.2 (1.20–1.37) in males; more slender pedipalps in males, with chela length/width ratio 4.34–5.54 (3.78–4.25); smaller size of males in the following measurements: carapace length 2.40–3.19 (3.15–3.78), metasoma III length 1.35–1.86 (1.80–2.28), femur length 2.05–2.75 (2.80–3.43), chela length 3.35–4.54 (4.94–6.16), chela width 0.71–0.97 (1.23–1.16), fixed finger length 1.63–2.3 (2.42–3.19), movable finger length 2.05–2.92 (3.01–3.85). *Vaejovis vorhiesi* can be further distinguished from *V. paysonensis* by the following characters (*V. paysonensis* characters follow in parentheses): chela more slender with chela length/width 4.24–4.95 (3.70–4.25) in females and 4.34–5.54, (3.68–3.91) in males; hemispermatophore lamina more slender with lamina length/width ratio 4.25–4.63 (3.50–4.25); male chela palm narrower with chela width 0.71–0.97 (1.13–1.13).

Vaejovis vorhiesi can be distinguished from *V. cashi* by the following characters (*V. cashi* characters follow in parentheses): subaculear tubercle present only as a low mound (well-developed and/or multiple tubercles present); larger size in all male measurement lengths except carapace length, larger hemispermatophore lamina length/hook length ratio 2.35–3.09 (1.93–2.00).

Vaejovis vorhiesi can be distinguished from *V. deboerae* by the following characters (*V. deboerae* characters follow in parentheses): modal count of chela fixed finger inner accessory denticles 5 (6); subaculear tubercles present only as a low mound (present 14% of the time as low mound, more often well-developed or present as multiple tubercles); carapace length shorter with 3.10–3.80 (4.00–5.24) in females and 2.40–3.19 (3.10–3.66) in males; chelae smaller with length 4.65–5.44 (5.28–8.13) in females and width 0.99–1.23 (1.26–1.90) in females, 0.71–0.97 (0.96–1.23) in males.

Distribution.—*Vaejovis vorhiesi* is known from the Huachua and Santa Rita Mountains, Cochise County and Santa Cruz County, in southeastern Arizona, USA.

Vaejovis lapidicola Stahnke 1940

Vejovis lapidicola Stahnke 1940:102 (original description); Stahnke 1974:135.

Vaejovis lapidicola: Kovarík 1998:147; Graham 2006:1–6, figs. 1–12; Graham 2007:1, 3, 13.

Type material.—Syntypes: 3 females (CAS, Type No. 15171, HLS no. 74.0, HLS no. 71.1), 1 male (CAS, Type No. 10170), 1.6 km E of Flagstaff, Coconino County, Arizona, USA.

Material examined.—USA: *Arizona*: Coconino County: Flagstaff, 35°12′N, 111°38′W, 4 June 1949, A.R. Phillips, 2 females (AMNH) & 2164 m, MNA, July 1947, J. Ferriss, 1 male (AMNH) & 17 June 1943, 1 female (AMNH); ca. 24 km N Sedona on US 89A, 35°02′N, 111°44′W, 19 August 2009, T. Anton, Casper & W.D. Sissom, 3 males, 1 female (AMNH);

Table 10.—Male measurements and ratios that overlap by 10% or less between two groups of montane *Vaejovis* scorpions grouped by seven geographic areas in Arizona. Actual percent overlap is listed in the column on the right.

Male measurements/ratios with 10% overlap or less			
Group 1	Group 2	Measurement or ratio	% Overlap
Huachuca	Sedona	CaL	2.88
Huachuca	Sedona	III L	7.44
Huachuca	Sedona	FemL	0
Huachuca	Sedona	ChL	0
Huachuca	Sedona	ChW	0
Huachuca	Sedona	FFL	0
Huachuca	Sedona	MFL	0
Huachuca	Sedona	ChL/ChW	0
Huachuca	Sedona	MFL/ChW	4.94
Huachuca	Sierra Ancha	ChW	0
Huachuca	Sierra Ancha	ChL/ChW	0
Huachuca	Sierra Ancha	MFL/ChW	0
Huachuca	Sierra Ancha	CaL/V L	0
Huachuca	Chiricahua	CaL	7.04
Huachuca	Chiricahua	III L	0
Huachuca	Chiricahua	V L	0
Huachuca	Chiricahua	V W	8.15
Huachuca	Chiricahua	FemL	0
Huachuca	Chiricahua	FemW	4.89
Huachuca	Chiricahua	ChL	3.32
Huachuca	Chiricahua	FFL	4.78
Huachuca	Chiricahua	MFL	0.29
Huachuca	Santa Catalina	CaL	7.37
Huachuca	Santa Catalina	ChW	1.75
Huachuca	Santa Catalina	ChL/ChW	4.11
Santa Rita	Sedona	CaL	0
Santa Rita	Sedona	III L	0
Santa Rita	Sedona	V L	0
Santa Rita	Sedona	V W	6.6
Santa Rita	Sedona	FemL	0
Santa Rita	Sedona	FemW	0
Santa Rita	Sedona	ChL	0
Santa Rita	Sedona	ChW	0
Santa Rita	Sedona	FFL	0
Santa Rita	Sedona	MFL	0
Santa Rita	Sedona	ChL/ChW	0
Santa Rita	Sedona	MFL/ChW	0
Santa Rita	Sedona	FFL/CaL	0
Santa Rita	Sedona	III L/III W	0
Santa Rita	Sierra Ancha	ChL	0
Santa Rita	Sierra Ancha	ChW	0
Santa Rita	Sierra Ancha	ChL/ChW	0
Santa Rita	Sierra Ancha	MFL/ChW	0
Santa Rita	Sierra Ancha	V L/V W	4.51
Santa Rita	Sierra Ancha	CaL/V L	0
Santa Rita	Chiricahua	III L	7.24
Santa Rita	Chiricahua	V L	8.54
Santa Rita	Chiricahua	FemL	4.99
Santa Rita	Chiricahua	FFL	4.26
Santa Rita	Chiricahua	MFL	7.77
Santa Rita	Chiricahua	V L/V W	8.66
Santa Rita	Chiricahua	CaL/V L	7.13
Santa Rita	Santa Catalina	CaL	0
Santa Rita	Santa Catalina	III L	0
Santa Rita	Santa Catalina	III W	0
Santa Rita	Santa Catalina	V L	0
Santa Rita	Santa Catalina	V W	0

Table 10.—Continued.

Male measurements/ratios with 10% overlap or less			
Group 1	Group 2	Measurement or ratio	% Overlap
Santa Rita	Santa Catalina	FemL	9.89
Santa Rita	Santa Catalina	FemW	0
Santa Rita	Santa Catalina	ChL	0
Santa Rita	Santa Catalina	ChW	0
Santa Rita	Santa Catalina	FFL	1.06
Huachuca/Santa Rita	Sedona	CaL	2.72
Huachuca/Santa Rita	Sedona	III L	6.76
Huachuca/Santa Rita	Sedona	FemL	0
Huachuca/Santa Rita	Sedona	ChL	0
Huachuca/Santa Rita	Sedona	ChW	0
Huachuca/Santa Rita	Sedona	FFL	0
Huachuca/Santa Rita	Sedona	MFL	0
Huachuca/Santa Rita	Sedona	ChL/ChW	0
Huachuca/Santa Rita	Sedona	MFL/ChW	4.7
Huachuca/Santa Rita	Sierra Ancha	ChW	0
Huachuca/Santa Rita	Sierra Ancha	ChL/ChW	0
Huachuca/Santa Rita	Sierra Ancha	MFL/ChW	0
Huachuca/Santa Rita	Sierra Ancha	CaL/V L	0
Huachuca/Santa Rita	Chiricahua	III L	6.12
Huachuca/Santa Rita	Chiricahua	V L	6.67
Huachuca/Santa Rita	Chiricahua	FemL	4.97
Huachuca/Santa Rita	Chiricahua	ChL	7.89
Huachuca/Santa Rita	Chiricahua	FFL	4.78
Huachuca/Santa Rita	Chiricahua	MFL	7.77
Huachuca/Santa Rita	Santa Catalina	CaL	6.92
Huachuca/Santa Rita	Santa Catalina	ChW	1.75
Sedona	Sierra Ancha	CaL	0
Sedona	Sierra Ancha	III L	0
Sedona	Sierra Ancha	V L	0
Sedona	Sierra Ancha	V W	3.25
Sedona	Sierra Ancha	FemL	0
Sedona	Sierra Ancha	FemW	0
Sedona	Sierra Ancha	ChL	0
Sedona	Sierra Ancha	ChW	0
Sedona	Sierra Ancha	FFL	0
Sedona	Sierra Ancha	MFL	0
Sedona	Sierra Ancha	FFL/CaL	5.03
Sedona	Sierra Ancha	III L/III W	0
Sedona	Sierra Ancha	CaL/V L	0
Sedona	Chiricahua	CaL	0
Sedona	Chiricahua	III L	0
Sedona	Chiricahua	III W	0
Sedona	Chiricahua	V L	0
Sedona	Chiricahua	VW	0
Sedona	Chiricahua	FemL	0
Sedona	Chiricahua	FemW	0
Sedona	Chiricahua	ChL	0
Sedona	Chiricahua	ChW	0
Sedona	Chiricahua	FFL	0
Sedona	Chiricahua	MFL	0
Sedona	Chiricahua	FFL/CaL	0
Sedona	Chiricahua	III L/III W	0
Sedona	Santa Catalina	ChW	0.54
Sierra Ancha	Chiricahua	CaL	0
Sierra Ancha	Chiricahua	III L	0
Sierra Ancha	Chiricahua	III W	0
Sierra Ancha	Chiricahua	V L	0
Sierra Ancha	Chiricahua	V W	0
Sierra Ancha	Chiricahua	FemL	0
Sierra Ancha	Chiricahua	FemW	0

Table 10.—Continued.

Male measurements/ratios with 10% overlap or less			
Group 1	Group 2	Measurement or ratio	% Overlap
Sierra Ancha	Chiricahua	ChL	0
Sierra Ancha	Chiricahua	ChW	0
Sierra Ancha	Chiricahua	FFL	0
Sierra Ancha	Chiricahua	MFL	0
Sierra Ancha	Chiricahua	ChL/ChW	0
Sierra Ancha	Chiricahua	FFL/CaL	0
Sierra Ancha	Santa Catalina	CaL	0
Sierra Ancha	Santa Catalina	III L	0
Sierra Ancha	Santa Catalina	III W	0
Sierra Ancha	Santa Catalina	V L	0
Sierra Ancha	Santa Catalina	V W	0
Sierra Ancha	Santa Catalina	FemL	0
Sierra Ancha	Santa Catalina	FemW	0.38
Sierra Ancha	Santa Catalina	ChL/ChW	0
Sierra Ancha	Santa Catalina	MFL/ChW	0
Santa Catalina	Chiricahua	CaL	0
Santa Catalina	Chiricahua	III L	0
Santa Catalina	Chiricahua	III W	0
Santa Catalina	Chiricahua	V L	0
Santa Catalina	Chiricahua	V W	0
Santa Catalina	Chiricahua	FemL	0
Santa Catalina	Chiricahua	FemW	0
Santa Catalina	Chiricahua	ChL	0
Santa Catalina	Chiricahua	ChW	0
Santa Catalina	Chiricahua	FFL	0
Santa Catalina	Chiricahua	MFL	0
Pinaleño	Sedona	CaL	0
Pinaleño	Sedona	III L	0
Pinaleño	Sedona	V L	0
Pinaleño	Sedona	FemL	0
Pinaleño	Sedona	FemW	0
Pinaleño	Sedona	ChL	0
Pinaleño	Sedona	ChW	0
Pinaleño	Sedona	FFL	0
Pinaleño	Sedona	MFL	0
Pinaleño	Sedona	FFL/CaL	1.63
Pinaleño	Sierra Ancha	ChW	0
Pinaleño	Sierra Ancha	ChL/ChW	0
Pinaleño	Sierra Ancha	MFL/ChW	0
Pinaleño	Chiricahua	CaL	1.18
Pinaleño	Chiricahua	III L	0
Pinaleño	Chiricahua	V L	6.58
Pinaleño	Chiricahua	FemL	0
Pinaleño	Chiricahua	FemW	7.64
Pinaleño	Chiricahua	ChL	0
Pinaleño	Chiricahua	ChW	4.03
Pinaleño	Chiricahua	FFL	0
Pinaleño	Chiricahua	MFL	0
Pinaleño	Chiricahua	FFL/CaL	2.71
Pinaleño	Santa Catalina	CaL	0
Pinaleño	Santa Catalina	III L	0
Pinaleño	Santa Catalina	III W	4.97
Pinaleño	Santa Catalina	V L	0
Pinaleño	Santa Catalina	FemL	0

Oak Creek Canyon cracked rock wall, 35°01′N, 111°44′W, 1707–1981 m, 21.7–25.7 km N Sedona, 35°01′N, 111°44′W, breeding pair, 10 September 1968, M. Cazier et al., 1 male, 1 female (AMNH) & scenic view from rim, ca. 24 km N Sedona, Hwy 89A, 22 August 1995, K.L. Semones & K.J. McWest, 1 male, 4 females, 3 juveniles (AMNH); Manzanita Camp, 35°55′N, 111°44′W, 25 July 1952, M. Cazier, W. Gertsch & R. Schrammel, 1 female (AMNH); Upper Oak Creek Canyon S of Flagstaff, 35°01′N, 111°44′W, 18 August 1949, L.F. Brady, 1 male (AMNH); 9.7 km N Sedona, 35°55′N, 111°44′W, 11 September 1962, V. Roth, 1 female (AMNH); 21.7–25.7 km N Sedona, 1707–1981 m, along grade cuts, 11 males, 4 females (AMNH) &1 female, 32 first instars (AMNH).

Diagnosis.—*Vaejovis lapidicola* (Fig. 7) can be distinguished from *V. paysonensis* by the following male characters (*V. paysonensis* characters follow in parentheses): hemispermatophore trunk width/hook length 1.08–1.25 (0.87–0.93); larger size in most measurements; fixed finger length/carapace length 0.76–0.84 (0.7–0.77); more elongate metasoma segment III with length/width ratio 1.2–1.37 (1.03–1.07). Female metasoma segment III length/width ratio also differs with 1.1–1.26 (1–1.13).

Vaejovis lapidicola can be distinguished from *V. cashi* by the following characters (*V. cashi* characters follow in parentheses): pectinal tooth modes for females 12, range 9–13 (11, range 10–13); modal count for inner accessory denticles of chela movable finger 7 (6), fixed finger 6 (5); metasoma segment III more slender with length/width 1.12–1.26 (0.89–1.07) for females and 1.2–1.37 (0.84–1.09) for males; fixed finger length/carapace length 0.72–0.88 (0.59–0.72) for females and 0.76–0.84 (0.58–0.68) for males; hemispermatophore lamina length/hook length 2.57–2.73 (1.93–2.0) and trunk width/hook length 1.08–1.25 (0.78–1.03).

Vaejovis lapidicola can be distinguished from *V. deboerae* by the following characters (*V. deboerae* characters follow in parentheses): movable finger inner accessory denticle mode 7 (6); subaculear tubercles mostly low and subtle, 90% (14%).

Vaejovis lapidicola can be distinguished from *V. vorhiesi* by the characters indicated in the diagnosis for that species.

Distribution.—This species is known from areas around the city of Flagstaff and between Flagstaff and the city of Sedona, Yavapai County and Coconino County, north-central Arizona, USA.

Vaejovis paysonensis Soleglad 1973

Vejovis paysonensis Soleglad 1973:363–371 (original description), figs. 16–22, 24, 26–28.

Vaejovis paysonensis: Kovařík 1998:147; Graham 2006:3, 6; Graham 2007:1, 3, 13; Ayrey 2009:9.

Type material.—Holotype: female, 40.2 km NE of Payson (34°18′N, 111°44′W), Gila County, Arizona, USA (AMNH). Paratypes: 1 male (AMNH; allotype), 7 females, 1 subadult female, 3 subadult males (MES?), same locality as holotype.

Material Examined.—USA: *Arizona*: Gila County: Payson, 34°14′N, 111°19′W, 5–11 May 1969, R. Erno, 2 females (CAS) & 3 May 1969, T. Lutz, 1 female (CAS) & 19 April 1905, W.L. Chapel, 1 female (CAS); 4.8 km N Experimental Station along Globe-Young Rd. at intersection of Armer Mt. Rd., in pine forest with some oak, dark fine soils, 33°50′N, 111°58′W, 1798 m, S.C. Williams, 3 males, 36 females, 6 juveniles (CAS).

Diagnosis.—*Vaejovis paysonensis* (Fig. 7) can be distinguished from *V. cashi* by the following characters (*V. cashi* characters follow in parentheses): pectinal tooth modes for males 12, range 12–13 (13, range 11–16); modal count for

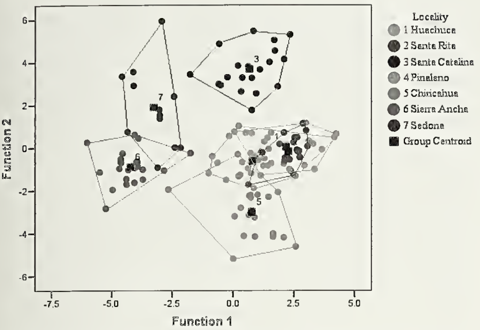

Figure 4.—Plot of all female specimens of montane *Vaejovis* scorpions measured according to the first two functions created from the discriminant function analysis. Function 2 has the highest correlation with all measurements while Function 1 is most highly correlated with metasoma segment III width.

inner accessory denticles of chela movable finger 7 (6), fixed finger 6 (5); subaculear tubercles mostly low and subtle mounds, 72% (0%); hemispermatophore lamina length/hook length 2.27–2.64 (1.93–2.00); male chela wider relative to length with length/width 3.68–3.91 (3.91–4.77).

Vaejovis paysonensis can be distinguished from *V. deboerae* by the following characters (*V. deboerae* characters follow in parentheses): pectinal tooth modes for males 13, range 11–16 (12, range 11–15), for females 11, range 10–12 (13, range 12–14); movable finger inner accessory denticle mode 7 (6); fixed finger length/chela length 0.46–0.50 (0.49–0.62) in females, 1.03–1.07 (1.07–1.25) in males; hemispermatophore lamina length/hook length 2.27–2.64 (2.62–3.28).

Vaejovis paysonensis can be distinguished from *V. vorhiesi* and *V. lapidicola* by the characters indicated in the diagnoses for those species.

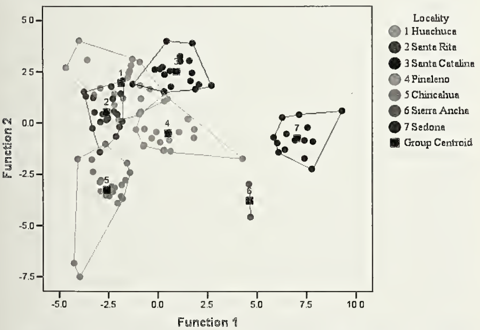

Figure 5.—Plot of all male specimens of montane *Vaejovis* scorpions measured according to the first two functions created from the discriminant function analysis. Function 1 is most highly correlated with chela width. Function 2 is most highly correlated with metasomal segment lengths but is highly correlated with all measurements except chela width.

Table 11.—Classification results for females from the SPSS discriminant function analysis output showing the numbers of specimens from each of seven groups of montane *Vaejovis* scorpions that were misclassified when using the functions that were created from the analysis. Overall, 86.8% of cases were grouped correctly. Groups: 1 = Huachuca, 2 = Santa Rita, 3 = Santa Catalina, 4 = Chiricahua, 5 = Pinaleño, 6 = Sierra Ancha, 7 = Sedona.

		Predicted group membership							
	Group	1	2	3	4	5	6	7	Total
Original count	1	14	2		4				20
	2	4	15		2				21
	3			20					20
	4	1	2		17				20
	5				1	18	1		20
	6						23		23
	7						1	11	12

Distribution.—Near the city of Payson and the Sierra Ancha Mountains, Gila County, central Arizona, USA.

Vaejovis cashi Graham 2007

Vaejovis cashi, Graham 2007:1–3, 6–10, 13 (original description), figs. 15–27; Ayrey 2009:3, 6, 8–10.

Type material.—Holotype: adult female, taken from under stones on the northwest flank of the Chiricahua Mountains, Arizona, USA, 31°55.406′N, 109°15.7057′W; 18 June 2001, D. Vernier (Private collection of M.R. Graham). Paratype: 1 adult female from same locality as holotype.

Material examined.—USA: *Arizona*: Cochise County, Chiricahua Mountains: Ash Spring, 9.7 km SW Portal, 31°51′N, 109°11′W, April 1965, B. & C. Durden, 1 female (AMNH); Rustler Park, 31°54′N, 109°16′W, 2591 m, 25–26 August 1952, B. Malkin, 7 males, 8 females, 5 juveniles (AMNH); 4.8 km SW Portal, 31°52′N, 109°10′W, 1 April 1966, B. Vogel, 1 juvenile (AMNH); 4.8 km S Portal, leaf litter, 31°52′N, 109°10′W, 16 March 1966, B. Vogel, 2 females, 1 juvenile (AMNH); 8 km S Portal, South Fork of Cave Creek, 31°51′N, 109°11′W, 30 May 1976, B. Warner, 7 females (AMNH); Cave Creek Canyon, 8 km W Portal, 31°52′N, 109°11′W, 14 August 1974, M. Cazier, 1 male, 3 females, 13 first instars (AMNH);

Table 12.—Classification results for males from the SPSS discriminant function analysis output showing the number of specimens from each of seven groups of montane *Vaejovis* scorpions that were misclassified when using the functions that were created from the analysis. Overall, 95.7% of cases were grouped correctly. Groups: 1 = Huachuca, 2 = Santa Rita, 3 = Santa Catalina, 4 = Chiricahua, 5 = Pinaleño, 6 = Sierra Ancha, 7 = Sedona.

		Predicted group membership							
	Group	1	2	3	4	5	6	7	Total
Original count	1	17	3						20
	2	1	19						20
	3			18					18
	4				19			1	20
	5					21			21
	6						2		2
	7							15	15

16–19 July 1952, M. Cazier & R. Schrammel, 3 females (AMNH); Roadcuts 19.3–24.1 km W Portal, Onion Saddle, 31°56′N, 109°16′W, 1981–2317 m, 21 July 1969, M. Cazier et al., 10 males, 5 females (AMNH); Rustler Park to 0.8 km N of park, along roadcuts, rock outcrops, cliffs, 31°54′N, 109°16′W, 22 July 1969, M. Cazier et al., 45 males, 12 females, 1 juvenile (AMNH); 8 km W Portal, 31°52′N, 109°11′W, 1829–1981 m, on banks of road cuts, rocky and dead plant material preferred, 14 August 1974, Cazier family, 65 males, 3 females (AMNH); 8 km W Portal, 31°52′N, 109°11′W, 4 July 1956, E. Ordway, 1 female (AMNH); Rustler Park, 31°54′N, 109°16′W, 25 February 1957, E. Ordway, 1 female (AMNH); East Turkey Creek, Coronado National Forest, Portal, 31°51′N, 109°20′W, 1951 m, soil in pinecones, 11 October 1961, E.A. Maynard, 1 male, 1 juvenile (AMNH); Turkey Creek, 31°51′N, 109°20′W, 28 June 1967, Gertsch & Hastings, 1 female (AMNH); Rustlers Camp, 31°54′N, 109°16′W, 1 June 1952, W.J. Gertsch, 2 males, 6 females (AMNH); Barfoot Meadow, 31°55′N, 109°16′W, 8 September 1963, W.J. Gertsch & V. Roth, 2 males, 6 females (AMNH); Barfoot Park, 16.1 km W Portal, 31°55′N, 109°16′W, 19 July 1964, Gertsch & Woods, 1 male, 1 female (AMNH); Barfoot Park, 31°55′N, 109°16′W, 27 June 1967, Gertsch & Hastings, 1 female (AMNH); Barfoot Park, 31°55′N, 109°16′W, 16 August 1964, Hastings, 2 females (AMNH); South Fork Cave Creek, 31°31.8′N, 109°6.5999′W, J. & W. Ivie, 1 male (AMNH); Southwestern Research Station can–traps, 31°52′N, 109°12′W, 29 July 1960, J. Cole, 2 females, 14 first instars (AMNH); Trail to Barfoot Lookout, 31°54′N, 109°16′W, 2597m, 16 July 1961, J. Cole & T. Ryan, 1 male (AMNH); Southwestern Research Station, 8 km W Portal, 31°52′N, 109°12′W, 22 April 1961, J. Rozen & R. Schrammel, 1 female (AMNH); Pinery Canyon, 31°56′N, 109°16′W, 10 May 1956, K. Statham, 1 female (AMNH); Rustlers Camp, 31°54′N, 109°16′W, 1 June 1952, M. Cazier, W. Gertsch & R. Schrammel, 2 males, 7 females (AMNH); Turkey Creek, 31°51′N, 109°20′W, 1829 m, 31 May 1952, M. Cazier, W. Gertsch & R. Schrammel, 2 males, 3 females (AMNH); Rustler Park, 31°54′N, 109°16′W, 22 August 1963, M. Muma, 1 female, 8 first instars (AMNH); Southfork, 31°52′N, 109°11′W, 6–13 May 1956, M. Statham, 1 female (AMNH); Cave Creek Canyon, 31°52′N, 109°11′W, August 1965, B. & C. Durden, 1 female (AMNH) & 0.16 km E Stewart Camp, 3 June 1973, O.F. Francke, 1 male, 7 females (AMNH) & 0.64 km W Stewart Camp, 3 June 1973, O.F. Francke, 1 male, 1 female (AMNH) & 1.13 km W Stewart Camp, 3 June 1973, O.F. Francke, 1 male, 4 females (AMNH) & 0–3.2 km W Sunny Flat Camp, 5 June 1973, O.F. Francke, 3 males, 63 females, 3 juveniles (AMNH) &10.5 km W Portal, 14 June 1973, O.F. Francke, 2 males, 22 females, 1 juvenile (AMNH); East Turkey Creek, 31°51′N, 109°20′W, 2012 m, 3 June 1973, O.F. Francke, 4 males, 2 females (AMNH); Ash Spring, 1.6 km NW Herb Martir Dam, 12.9 km W Portal, 31°51′N, 109°11′W, 31 July 1965, R. Hastings, 1 female (AMNH); East Turkey Creek, 31°51′N, 109°11′W, 1920m, 29 July 1972, R. Zweifel, 1 female (AMNH); 8 km W Portal, on South Fork, 31°51′N, 109°11′W, 17 April 1964, V. Roth, 1 female (AMNH); 12.9 km W Portal, toward falls, 31°50′N, 109°12′W, 8 April 1963, V. Roth, 2 males, 1 female (AMNH); Rustler Park, 17 August 1963, V. Roth, 1 female (AMNH); South Fork, 31°52′N, 109°11′W, 13 July 1963, V. Roth, 1 female (AMNH); 8 km W Portal, South fork of Cave Creek, 31°52′N, 109°11′W, 17–19 April 1961, W.J. Gertsch, 1 male, 4 females (AMNH); 8 km W Portal, Southwestern Research Station, 31°52′N, 109°12′W, 5–15 August 1955, W.J. Gertsch, 1 female (AMNH); 11.3 km W Portal, 31°52′N, 109°11′W, 4 August 1955, W.J. Gertsch, 1 female (AMNH); Barfoot, 31°55′N, 109°16′W, 1 August 1955, W.J. Gertsch, 1 female (AMNH); Barfoot Park, 31°55′N, 109°16′W, 6 July 1962, W.J. Gertsch, 5 males, 11 females (AMNH); Pinery Canyon, 31°56′N, 109°16′W, 8 September 1950, W.J. Gertsch, 1 female (AMNH); South Fork Cave Creek, 11 September 1950, W.J. Gertsch, 3 males, 3 females (AMNH); South Fork Cave Creek, 31°52′N, 109°11′W, 6.4 km W Portal, 9 September 1964, W.J. Gertsch, 2 females (AMNH); Southwestern Research Station, 31°52′N, 109°12′W, August 1960, Zweifel et al., 5 males, 1 juvenile (AMNH).

Diagnosis.—*Vaejovis cashi* (Fig. 7) can be distinguished from *V. deboerae* by the following characters. (*V. deboerae* characters follow in parentheses): pectinal tooth count mode for females 11, range 10–13 (12, range 11–15); chela fixed finger inner accessory denticle mode 6 (5); smaller body size in all measurements; hemispermatophore blade length/hook length 1.93–2.00 (2.62–3.28).

Vaejovis cashi can be distinguished from *V. vorhiesi*, *V. lapidicola*, and *V. paysonenis* by the characters indicated in the diagnoses for those species.

Distribution.—Known from the Chiricahua Mountains in Cochise County, southeastern Arizona, USA.

Vaejovis deboerae Ayrey 2009

Vaejovis deboerae Ayrey 2009:1–10 (original description), figs. 1–4, 6, 8, 10, 11, 14, 15.

Type material.—Holotype: female, Mt. Lemmon, Santa Catalina Mountains, 32°23.21667′N, 110°41.75′W, intersection of Willow Canyon Circle and Catalina Highway, Pima County, Arizona, USA, 2142 m, 25 August 2008, R.F. Ayrey (CAS). Paratypes: 1 male, 2 females, (CAS), same locality as holotype.

Material examined.—USA: *Arizona*: Pima County, Santa Catalina Mountains: 32°26′N, 110°45′W, 12 April 1936, O. Bryant, 1 female (AMNH); 32°26′N, 110°47′W, 1 October 1938, O. Bryant, 2 females (AMNH); 32°26′N, 110°47′W, 25 May 1937, O. Bryant, 1 male, 4 females (AMNH); Rose Lake, 32°23′N, 110°42′W, 6 October 1973, E. Oliver, 1 male (AMNH); Mt. Lemmon, 32°26′N, 110°45′W, 8 March 1968, H.L & L.L. Stahnke, 1 male (CAS); Sabino Canyon, 32°20′N, 110°46′W, 6 June 1952, M. Cazier, W. Gertsch & R. Schrammel, 1 male (AMNH); Summerhaven, 32°26′N, 110°47′W, 6 June 1952, M. Cazier, W. Gertsch & Schrammel, 4 females (AMNH); Summerhaven, 32°26′N, 110°47′W, 22 August 1950, M.A. Cazier, 1 female (AMNH); Tucson, 32°26′N, 110°45′W, O. Bryant, 1 female (AMNH); Mt. Lemmon 19 June 1954, B. & J. Liming, 3 females (CAS) & 2804 m, 15 August 1974, E. Minch, 1 male (AMNH) & 32°24.6375′N, 110°42.8878′W, 2420 m, 15 June 2007, Z. Valois, 1 male, 2 females, 1 subadult female (AMNH/AMNH-ARA 00002515) & Mt. Lemmon, 32°26′N, 110°45′W, 8 March 1968, H.L & L.L. Stahnke, 1 male (CAS) & vicinity of Summerhaven, 32°14.4′N, 110°27′W, 21 May 1963, W.J. Gertsch & W. Ivie, 1 female, 3 subadult females, 2 juveniles (AMNH) & Summerhaven, 32°26′N, 110°45′W, 10 September 1963, W.J. Gertsch & V. Roth, 1 female, 1 subadult female (AMNH); 32°23′N, 110°41′W, on the road to Mt. Lemmon, Molina Basin, 1524–1829m, 19 August 1995, P. Hyden & D. Wagner, 1 male (AMNH); Sabino Canyon, 32°20′N, 110°46′W, 8 June 1955, R.B. & J.M. Selander, 1 female (AMNH); General Hitchcock Tree, 26 August 1951, T. Cohn, 1 female (AMNH); Bear Canyon Campground, 32°22′N, 110°41′W, 1981 m, 24 July 1965, W.J. Gertsch & R. Hastings, 3 males, 2 females (AMNH); 8 km S Oracle, 32°33′N, 110°44′W, 25 July 1949, W.J. & J.W. Gertsch, 1 juvenile (AMNH); Peppersauce Cave Canyon, 32°32′N, 110°43′W, 21 April, 1961, W.J. Gertsch, 4 female (AMNH); Tucson, Upper Bear Canyon, 32°22′N, 110°41′W, 15 June 1973, D. Richman, 1 female (AMNH); Coronado National Forest, Santa Catalina Hwy, on and near Bear Wallow Rd., between mile marker 22 & 23, rocky road cut slopes, 32°24.495′N, 110°43.317′W, 2375 m, Site 13, 22 June 2006, W. Savary, R. Mercurio, 4 males, 10 females (AMNH/AMNH-ARA 0002507); Coronado National Forest, Santa Catalina Hwy, on and near Incinerator Rd., between mile marker 19 & 20, granitic rocky road cut slopes, 32°24.664′N, 110°43.325′W, 2464 m, Site 14, 22 June 2006, W. Savary & R. Mercurio, 6 males, 2 femlaes, 1 subadult female (AMNH/AMNH-ARA 00002506).

Diagnosis.—This species may be distinguished from the other described species in Arizona by the characters given in the diagnoses of those species.

Distribution.—Known from the Santa Catalina Mountains, Pima County, southern Arizona, USA.

Vaejovis electrum sp. nov.
Figs. 6, 7, 8

Type material.—Holotype male, Wet Canyon (32°38′N, 109°48′W), Forest Camp, Graham Mt., Graham County, Arizona, USA, 12–13 September 1952, B. Malkin (AMNH). Paratypes: 2 males, 3 females, from same locality as holotype (AMNH).

Other material examined.—USA: *Arizona*: Graham County, Pinaleño Mountains: Wet Canyon, Forest Camp, Graham Mt., 32°38′N, 109°48′W, 12–13 September 1952, B. Malkin, 3 males, 6 females, (AMNH); 32°38′N, 109°49′W, 2743 m, 10 September 1937, Bryant, 1 male, 1 female (AMNH); 32°38′N, 109°49′W, 15 September 1940, Bryant, 2 males, 2 females, 12 first instars (AMNH); 38°39′N, 109°49′W, 2256 m, 10 September 1937, Bryant, 2 females (AMNH); 38°38′N, 109°49′W, 16 August 1933, Bryant, 1 male (AMNH); 2.6 km S Arcadia Campground, 32°38.167′N, 109°49.453W, 2179 m, 31 May–1 June 2000, W.D. Sissom et al., 1 male (WDS); Mt. Graham, 1.4 km S Arcadia Campground, 32°38.633′N, 109°49.102W, 31 May–1 June 2000, W.D. Sissom et al., 1 male, 3 female (WDS); 6.4 km SW Cottonwood, 8 June 1973, O.F. Francke, 1 male, 1 female (AMNH); Arcadia Campground, 32°38′N, 109°49′W, 4 April 1969, G.J. Doleyard, 2 females (AMNH); Wet Canyon, under rock on south-facing slope, 30 m above stream, 32°38′N, 109°48′W, 1942 m, 15 June 1967, K. Brown, 1 female (AMNH); Turkey Flat, 32°37′N, 109°49′W, 15 September 1973, R. Kempton, 3 males, 2 females, 10 juveniles (AMNH); south of Safford, 2 September 1973, R. Kempton, 1 male, 1 female (AMNH); Pinecrest (also Turkey Flat), 32°37′N, 109°49′W, 13 September 1950, W.J. Gertsch, 3 males, 6 females, 1 juvenile (AMNH); Cluff Dairy turnoff, Swift Trail Rd., deep in Ponderosa pine log on ground, 32°38′N, 109°49′W, 2256 m, 10 July 1966, W.L. Minckley, 4 females (AMNH); Arcadia Campground, 32°38′N, 109°49′W, 31 May 2000, W.D. Sissom et al., 1 male, 16 females (WDS); Hwy. 366 into Coronado National Forest, climbing Mount Graham, just past mile marker 126, 19 km from junction with Hwy. 191, under rocks in pine forest, 32°38.5517′N, 109°49W.1033′, 1684 m, 25 July 2007, J. Huff, 1 male, 3 females, 1 juvenile (AMNH); Hwy. 366 into Coronado National Forest, climbing Mount Graham, "Ladybug Trail No. 329" at mile marker 131, 26.6 km from junction with Hwy. 191, under rocks in pine forest, 32°37.35′N, 109°49.4033′W, 25 July 2007, J. Huff, 1 male, 3 females (AMNH).

Etymology.—Specific epithet is from the Latin word *electrum*, meaning amber in reference to the amber-like coloration of this species, and is used as a noun in apposition.

Diagnosis.—*Vaejovis electrum* can be distinguished from *V. lapidicola* and *V. paysonensis* by 1) having 6 inner accessory denticles on the movable finger instead of 7, and 2) having a smaller chela width. It can be distinguished from *V. vorhiesi* by 1) usually having multiple subaculear tubercles or well-developed subaculear tubercles and rarely having only a subtle, low mound for a tubercle, 2) having lower pectinal tooth counts, mode 13 for males and 12 for females, and 3) having hemispermatophore lamina length/width 3.89–4.63 instead of 2.35–3.09. It can be distinguished from *V. cashi* by 1) having a higher pectinal tooth count mode for females (12 instead of 11), 2) having hemispermatophore lamina length/hook length ratio 2.2–2.8 instead of 1.93–2.0, and 3) by having an overall larger body size, especially in the male. *Vaejovis electrum* can be distinguished from *V. deboerae* by 1) having a mode of 5 inner accessory denticles on the chela fixed finger instead of 6, and 2) having a smaller body size, especially in males, but particularly smaller in carapace length and metasoma segment V length for both sexes. *Vaejovis electrum* can be distinguished from *V. feti*, a New Mexican species, by 1) having greater pectinal tooth count modes (males: 13 instead of 11–12; females: 12 instead of 10), 2) having well-developed subaculear tubercles instead of tubercles being present as only a low mound, and 3) having larger body size.

Description.—The following description is based mostly on the male holotype; female characters, where notably different, are indicated.

Coloration: Base color of body surfaces light yellow-orange to brown (Fig. 7). Carapace with distinct fuscous pattern. Coxosternal region light yellow with no fuscous markings. Pretergites with fuscous posterior margin except fuscosity weak to absent along midline. Post-tergites with little to no markings along midline and possessing lateral fuscous blotches. Sternites yellow with no fuscous markings except for extreme lateral edges. Pectines pale yellow; sternite V with pale yellow patch on posterior margin (absent in females). Metasomal carinae with underlying fuscous markings (except for ventral carinae of metasomal segments I and II). Dorsal surface of metasoma with triangle or arrow-shaped fuscous pattern on segments I–III, longitudinal band of fuscosity on

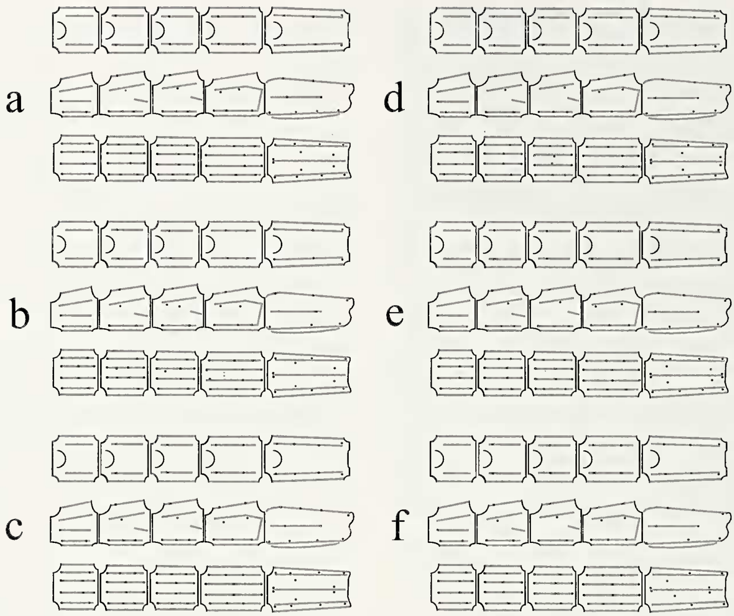

Figure 6.—Setal maps displaying (from top to bottom) a dorsal, lateral and ventral view of the metasoma with plots of the metasomal setae from six species of *Vaejovis* scorpions from different montane locations in Arizona, USA: A. *V. vorhiesi* Stahnke 1940 from the Huachuca Mountains; B. *V. lapidicola* Stahnke 1940 from Flagstaff; C. *V. paysonensis* Soleglad 1973 from the Sierra Ancha Mountains; D. *V. cashi* Graham 2007 from the Chiricahua Mountains; E. *V. deboerae* Ayrey 2009 from the Santa Catalina Mountains; F. *V. electrum* sp. nov. from the Pinaleño Mountains.

IV and two longitudinal lateral bands on V. Ventrolateral and lateral supramedian intercarinal space with fuscous pattern on posterior portion. Telson yellow; aculeus dark brown; ventral median marked by fuscous band. Pedipalps: femur, patella, and chela light yellow with faint dusky markings, especially near base of fingers and along external carinae; denticles of finger yellow-orange to orange-brown. Legs light yellow with some fuscous markings on prolateral surfaces of femur, patella, tibia, and basitarsus with distinct banded pattern on patella; telotarsus yellow.

Prosoma: Carapace slightly longer than posterior width. Anterior margin slightly indented but not bilobed, with six anterior-facing setae. Carapace finely covered with minute granules. Two median eyes present; two rows of three lateral eyes with seta behind each lateral eye row.

Mesosoma: Tergites I–VI: median carina covered by granules and increasingly distinct on each successive segment from weak on I to moderate on VI; submedian carinae indistinct, merged into general granulation associated with the lateral markings. Tergite VII: median carina present as a moderate, granulated hump about two-thirds the length of the post-tergite up from the posterior margin; submedian and lateral carinae strong, irregularly crenulate; submedian carinae originating from about two-thirds the length of the post-tergite up from the posterior margin and extending to the posterior margin; lateral carinae spanning the length of the post-tergite. All tergites possessing granules with larger granules on posterior half of the segment; large granules on lateral surface of VIII. Male genital opercula without median longitudinal membranous connection (in females connected on anterior 4/5), genital papillae well developed (absent in females). Pectinal tooth count 13/13 (12–14 in males, 11–13 in females). Sternites III–VI finely porous, lustrous medially; finely granular and less lustrous laterally; moderately setose throughout. Sternite III with posterior white patch in males. Sternite VII with lateral carinae present as an irregular row of slightly enlarged granules.

Metasoma: (Fig. 8g) Segment I 1.33 times wider than long; II 1.13 times longer than wide, III as long as wide, IV 1.24 times longer than wide, V 1.96 times longer than wide. Segments I–IV: Carination: Dorsolateral carinae on I–IV strong, crenulate to serrate; distal-most denticles on I–IV distinctly enlarged, spinoid. Lateral supramedian carinae on I–IV strong, crenulate; distal-most denticles distinctly enlarged, spinoid on I–III; widely flared on IV. Lateral inframedian carinae on I complete, moderate, granular; on II present on posterior one-half, granular; on III present on posterior one-quarter, granular; on IV absent. Ventrolateral carinae on I–III moderate, granulate to crenulate; on IV moderate, crenulate. Ventral submedian carinae on I weak,

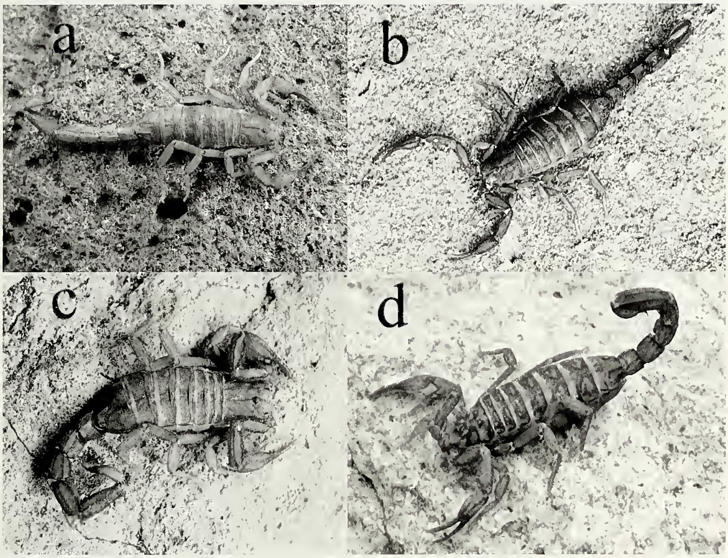

Figure 7.—Live specimens of montane *Vaejovis* scorpions from Arizona: a. *V. lapidicola* Stahnke 1940; b. *V. cashi* Graham 2007; c. *V. paysonensis* Soleglad 1973; d. *V. electrum* sp. nov. All photos courtesy of W.D. Sissom.

granular; on II–IV moderate, crenulate. Dorsal intercarinal spaces on I–IV finely minutely granular, lustrous. Dorsolateral intercarinal spaces on I–IV finely granular, with sparse coarse granulation. Lateral faces mostly with minute granulation and some larger granules interspersed throughout. Ventral spaces finely, minutely granular. Segment I–IV setation: dorsolaterals, 0:1:1:2; lateral supramedians, 0:1:1:2; lateral inframedians, 1:0:0:0; ventrolaterals, 2:2:2:2; ventral submedians, 3:3:3:3; setae of ventromedian intercarinal spaces, 0:0:0:0. Segment V: Dorsolateral carinae moderate, basal one-third serrate, remaining distal portion smooth. Lateromedian carinae present on anterior three-fifths, weak, granular. Ventrolateral and ventromedian carinae strong, serrate. Dorsal proximal transverse furrow strong, smooth, lustrous; longitudinal furrow weak, shallow. Dorsal and lateral intercarinal spaces finely granular; ventral intercarinal spaces, sparsely decorated with course granules. Segment V setation: dorsolaterals, 3; lateromedians, 1; ventrolaterals, 3; ventromedian, 4.

Telson: (Fig. 8g) All surfaces smooth, lustrous. Vesicle with about 18 pairs of setae; aculeus with a few setae on base. Subaculear tubercle well-developed, simple. Aculeus 36% of telson length.

Pedipalp: Femur (Fig. 8e, f) tetracarinate. Prodorsal and proventral carinae strong, crenulate. Retrodorsal carina moderate, irregularly granular. Retroventral carina moderate, smooth to finely granular. Prolateral face with about 8 large granules medially; dorsal, ventral and retrolateral faces finely granular with sparse coarser granulation. Trichobothrial pattern Type C, orthobothriotaxic (Vachon 1974). Setation: prolateral face with 1 supramedial seta, 2 inframedial setae; retrolateral face with 2 medial setae.

Patella: Pentacarinate. Prodorsal carina strong; proventral carinae strong, crenulate. Retrodorsal and retroventral carinae moderate, smooth. Promedial carina moderate, irregularly granular. Dorsal, ventral and retrolateral intercarinal spaces finely granular, prolateral intercarinal space finely to moderately coarsely granular. Trichobothrial pattern Type C, orthobothriotaxic (Vachon 1974). Setation: prolateral face with 2 supramedial setae; 2 inframedial setae.

Chela: (Fig. 8a–d) Essentially acarinate, with positions of keels indicated in cross section by faint, rounded elevations and underlined with fuscous markings; intercarinal spaces finely granular. Dentate margin of fixed finger with primary denticle row divided into six subrows by five larger granules; six inner accessory denticles, with the distal-most paired with the terminal denticle, the next four with enlarged primary row granules. Dentate margin of movable finger with primary denticle row broken up into six subrows by five enlarged denticles; distal-most subrow consisting of a single apical denticle and its enlarged primary row denticle; six inner accessory denticles, with the distal denticle paired with the terminal denticle and the next five paired with enlarged primary row denticles. Chela length/width ratio 4.06; fixed finger length/carapace length ratio, 0.68; fixed finger length 49% of total chela length. Trichobothrial pattern Type C, orthobothriotaxic (Vachon 1974).

Legs: Prolateral surface of patella on legs I–IV bearing a single seta. Proventral margin of patella bearing two setae on I–II, three setae on III–IV. Retroventral margin of patella

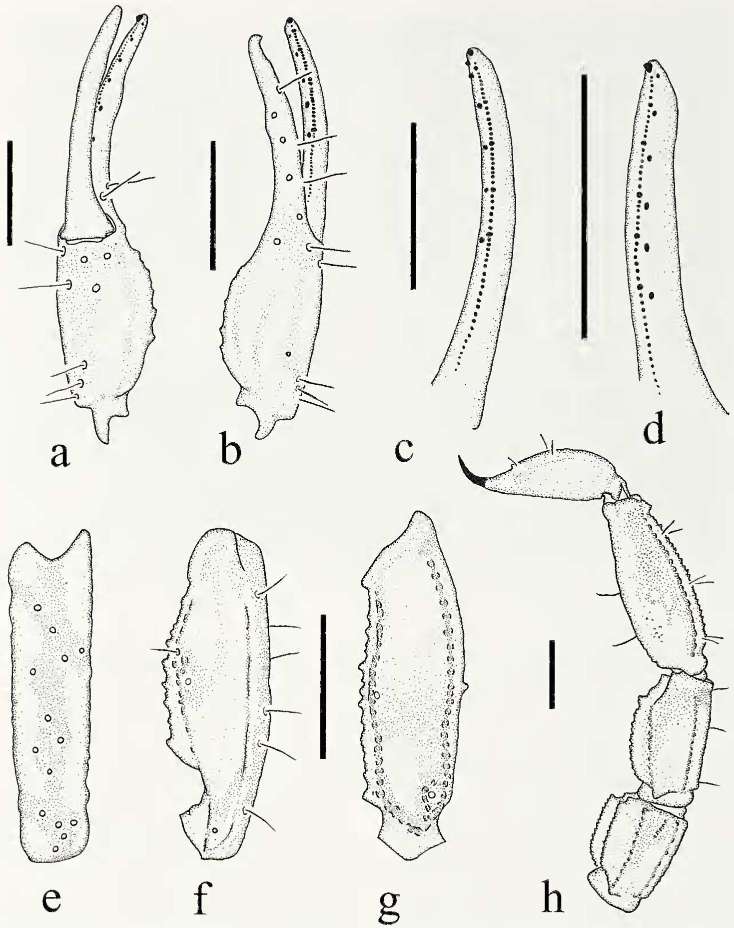

Figure 8.—Illustrations of various features of *Vaejovis electrum* sp. nov. Scale bars to the left of each figure represent 1 mm, except for patellae, which were not measured. Note in A and B that the bulge of inner margin of the fixed finger is an aberration in the type specimen and not an artifact of illustration. a. Ventral aspect of pedipalp chela; b. Dorsal aspect of pedipalp chela; c. Pedipalp chela movable finger; d. Pedipalp chela fixed finger; e. Dorsal aspect of pedipalp femur; f. Dorsal aspect of pedipalp patella; g. External aspect of pedipalp patella; h. Lateral view of metasomal segments III–V and telson.

bearing three setae on I–IV. Basitarsus on legs I–III with two ventrosubmedian and one retrolateral rows of spinules; prolateral ventrosubmedian spinule extending proximally only a short distance from distal-most seta; spinule rows interrupted at irregular intervals by large, stiff setae. Leg IV lacking spinule rows. Telotarsus on all legs with single ventromedian row of spinules.

Hemispermatophore (dissected from topotype male): Measurements (in mm): lamina length 1.17, lamina width 0.30, hook length 0.53, trunk width 0.53. Lamina length/lamina width ratio 3.89, lamina length/hook length ratio 2.19, trunk width/hook length ratio 1.Sperm plug lacking spines.

Measurements of holotype male (in mm): Total length (estimated), 43.00; carapace length, 2.62; metasoma III length 1.46, width 1.46; metasoma V length 2.74, width 1.40; femur length 2.39, width 0.70; chela length 3.78, width 0.93; fixed finger length 1.86; movable finger length 2.33.

Variation.—As with other scorpions in this group, *V. electrum* exhibits sexual dimorphism in morphometrics. Ranges for measurements of males with females in parentheses (all measurements in mm): carapace length 2.56–3.03 (3.2–3.72); metasoma III length 1.46–1.75 (1.57–2.04), width 1.19–1.60 (1.6–1.93); metasoma V length 2.68–3.18 (3.11–3.72), width 1.16–1.50 (1.51–1.86); femur length 2.24–2.62 (2.74–3.51), width 0.64–0.76 (0.81–0.96); chela length 3.61–4.45 (4.72–5.44), width 0.81–1.03 (1.05–1.28); fixed finger length 1.80–2.21 (2.39–2.79); movable finger length 2.24–2.78 (2.86–3.40). Ratios for males with females in parentheses: chela length/width 4.03–4.71 (3.94–4.72); femur length/width 3.20–3.64 (3.06–3.75); metasoma III length/width 0.98–1.28 (2.32–2.89); metasoma V length/width 1.92–2.43 (1.84–2.22). Other variation can be seen in Tables 1–7.

Distribution.—Known from the Pinaleño Mountains, Graham County, Arizona, USA.

DISCUSSION

Most species descriptions are accompanied by a section detailing the variation in the new species being described and are based on multiple specimens. The ability to distinguish one species from another stems from an understanding of that intraspecific variation. When this variation is not taken into consideration, new species can be described without consistent diagnostic characters that identify that species. For example, a new species may be described and diagnosed from related species by the presence of a few characters found in the holotype and a few other specimens when a larger sample size would have revealed that the characters overlap so greatly as to be useless in diagnosing the species. In such a situation, had a larger sample size been collected and examined for the initial description of the species, it would have been apparent that the character was not useful for distinguishing the species from others.

This scenario has occurred with some of the "*vorhiesi* complex" species from Arizona. The original description of *V. cashi* was based upon only two specimens (Graham 2007). One of the characters Graham (2007) used to distinguish *V. vorhiesi* from *V. cashi* was the number of denticles on the third median subrow of the pedipalp chela movable finger. However, the variability was great in the number of denticles per subrow. Graham (2007) stated that *V. cashi* should have 6 or 7 denticles on the third subrow but in the sample of 10 specimens from the Chiricahua Mountains used in this study, 11 of the 20 movable fingers had 8–9 denticles, which was the range Graham gave for *V. vorhiesi*. It is not surprising that with only two specimens of *V. cashi* the ranges he found were completely non-overlapping.

This also happened with the lateral inframedian carinal differences reported by Ayrey (2009). *Vaejovis deboerae* is reported as having longer carinae on segments II and III of the metasoma. Although the *V. deboerae* specimens I examined may have had a slightly greater proportion of specimens with long lateral inframedian carinae, many of the other species also had specimens with long lateral inframedian carinae. *Vaejovis deboerae* is also supposed to be different from the other species in that segment IV has the lateral inframedian carina present on the distal 2/5 of the segment. The distal end of the segment is where the carina originates, so if a carina is present at all, it is usually found in the distal 2/5 of the segment. Therefore I believe Ayrey was attempting to say that the carina was present on at least the distal 2/5 of the segment. In fact, 29.2% of *Vaejovis deboerae* specimens examined in this study did not have the lateral inframedian carina at all and only 62.5% had the carina present on at least the distal 2/5 of the segment. Additionally, 53.9% of *V. cashi* and 66.2% of *V. electrum* had the carina present on at least the distal 2/5 of metasomal segment IV. That means there is about the same probability to identify a specimen of *V. deboerae* correctly as there is to misidentify *V. cashi* or *V. electrum* specimens as *V. deboerae*.

It must be admitted that the current study also suffers from some low sample sizes. For example, only 2 male specimens of *V. paysonensis* were examined. The rule for reporting measurements with ranges overlapping 10% or less was determined *a priori* to minimize any biases of character reporting. For that reason, measurements of male *V. paysonensis* were included. To exclude them would introduce bias, even though a larger sample size would have been much preferred.

For this study, I used the phylogenetic species concept, which delimits species as the smallest group of individuals that forms a monophyletic group and displays consistent distributions of characters (Donoghue 1985). This species concept has been used in describing scorpion species previously (Prendini 2001). Although many of the traits used to diagnose these species do overlap, the amount of characters, along with the minimal overlap (10% rule), suggest that these species are indeed distinct. Further evidence is found in the discriminant function analysis, especially for males, which misclassified less than 10% of the specimens.

ACKNOWLEDGMENTS

I sincerely thank the following individuals: Dr. W. David Sissom for all of his guidance and advice on distinguishing these species and for obtaining the specimens to examine; Dr. Lorenzo Prendini for his comments regarding species questions in taxonomy; Dr. Richard Kazmaier for his assistance with some of the statistics; Dr. Raymond Matlack for his review of the manuscript; curators Dr. Griswold (CAS) and Dr. Prendini (AMNH) for loaning the material examined and Dr. Sissom for borrowing material on my behalf. This project was supported in part by NSF BIO-DEB 0413453 grant to Dr. Prendini.

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Manuscript received 27 January 2011, revised 10 August 2011.